PB90-200700

Soil Mapping Concepts for Environmental Assessment

(U.S.) Pacific Northwest Forest and Range Experiment Station
Corvallis, OR

Prepared for:

Corvallis Environmental Research Lab., OR

1990

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. REC
EPA/600/D-90/012		PB90-200700

4. TITLE AND SUBTITLE	5. REPORT DATE
Soil Mapping Concepts for Environmental Assessment	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) D. A. Lammers and M. G. Johnson	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS USDA-FS and U.S. EPA, ERL-Corvallis; NSI, ERL-Corvallis, OR	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS US Environmental Protection Agency Environmental Research Laboratory 200 SW 35th Street Corvallis, OR 97333	13. TYPE OF REPORT AND PERIOD COVERED Symposium Paper
	14. SPONSORING AGENCY CODE EPA/600/2

15. SUPPLEMENTARY NOTES
1990. Soil Sci.Soc. Amer. Special Publication, "Spatial Variability and Map Units of the Soil Survey

16. ABSTRACT

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to Public	Unclassified	18
	20. SECURITY CLASS (This page) Unclassified	22. PRICE A-03

EPA Form 2220-1 (9-73)

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

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EPA/600/D-90/012

Soil Mapping Concepts for Environmental Assessment[1]

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ABSTRACT

Spatial variability of soils in the landscape and how this variability is represented by soil maps and portrayed in map unit descriptions are critical for assessing many of today's pressing environmental concerns. Traditional concepts used in mapping, naming, defining and correlating map units need to be redirected from a use or purpose bias to one that uses soil properties as the basis for correlation. Map unit delineations need to represent real segments of the landscape by capturing discrete soil patterns that function as workable stratifications of the landscape and provide detailed soils information for use in environmental assessment. An estimate of the proportion of map unit components can be made with quantifiable uncertainty bounds. By grouping soils into response classes, minor soil components, important to understanding the ecology of landscape and assessing environmental concerns, can be retained in regional-scale data bases. To meet the need for global-scale assessments, a soil and landscape attribute based framework is proposed.

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Scientists from many disciplines are recognizing the vital role that soils play in mitigating the effects of natural and anthropogenic perturbations (e.g., fire, acid rain, global climate change) of ecosystems. Because environmental problems are regional, continental or global in scale, an alternate strategy for developing soil data bases that capture local-scale soil spatial variability and provide a mechanism for maintaining its integrity across scales of extrapolation needs to be developed.

In this paper, we explore an approach to linking soil mapping data needed for local-scale process studies to global-scale data bases for environmental assessment. Changes to traditional concepts used in the design of map units and interpretation of soils are recommended to facilitate linking of data bases from are scale to another. Current examples of regional and global soil data bases are presented and a global framework approach for nesting mapping data bases of different scales is proposed.

A general hypothesis for using soils in environmental assessments can be stated as follows: the kinds of soil and their distribution in the landscape affect the response of ecosystems to environmental stress. We assume that soil properties in concert with other ecosystem attributes (i.e., climate, topography, biota and lithology) are related to identifiable landscape segments that can be mapped. Therefore, if we can adequately map and characterize the soils and develop models that simulate soil processes for individual soils or classes of soils, and, if we can aggregate effects for landscape units and extrapolate results to regions, we can project the effect of a stress on a region. Soil processes are influenced by both internal properties and by characteristics of soils in neighboring landscape segments. Consequently, our understanding of relationships among soils and environmental effects is limited by pedologist's ability to capture data

about soils and their distribution in a landscape at a scale appropriate for linking data to process models.

CONCERNS WITH TRADITIONAL SOIL SURVEYS

Traditional concepts that have evolved with soil mapping need to be examined as a basis from which to propose changes that will facilitate adaptation of soils information to geographic information systems, electronic data bases and global assessments. Products of the National Cooperative Soil Survey (NCSS) in the United States have evolved around interpretations needed for farm planning and conservation of the agricultural soil resource. Purity standards placed on the extent of similar and dissimilar components of map units and on soil mapping were a reflection of the perceived use of the maps (Soil Survey Staff, 1983). The inaccuracy of these map unit purity standards has been reviewed in Buol et al. (1980) and Wilding (1988), and a shift from the rigid tolerances of map unit composition has been reported by Brown (1988). In the past, emphasis was on interpretative units rather than naturally occurring delineations on the landscape. The resulting map units were, therefore, focused on interpretation for a specific purpose. Although satisfactory for the specific purpose for which the mapping was done, this approach may not have produced the best soil data base for other applications.

Soil Taxonomy has provided a system to classify soils described in the mapping process, but has been used as a correlation shoehorn to force decisions on which soils were similar or dissimilar. This comprehensive classification system has focused attention on boundaries of classes and has undoubtedly biased the selection of modal

representatives of a class. A soil became "different" if one or more properties fell outside the limits of family criteria. Nettleton and Brasher (1989) have proposed a solution to this "taxadjunct problem" that has resulted from application of rigid taxonomic limits to soil series and other "taxonomic units". Taxonomy provided a framework for relationships among soils, and among soils and the factors responsible for their character (Soil Survey Staff, 1975). Taxonomic classification does not, however, form soils into the best groups for making predictions for a particular purpose. Although taxonomic classes help us to recognize fundamental differences in soils, we must regroup soils into classes that relate to specific problems. For example, soils were grouped on properties expected to have an important affect on surface water chemistry for the assessment of regional affects of acidic deposition (Lee et al. 1989b).

HOW ARE SOIL SURVEYS USED IN ENVIRONMENTAL ASSESSMENTS?

Environmental assessments are often used to make regional predictions that answer a variety of "what if" questions concerning stress on terrestrial ecosystems. Soils are integral in the natural mitigation of ecosystem perturbations and are being included more and more in the assessment of the extent of environmental damage or change. Soils within a region of environmental concern can be inventoried and characterized, and process models developed that incorporate this information to predict the response of regional systems. The specific location of soils within a landscape segment may not always be needed to determine the cumulative response for that segment of the landscape. Instead, by combining the effects of individual

soils or groups of soils and the extent of each in the region, cumulative effects on the region may be determined. Spatial relationships among components of map units and among map units that comprise landscape systems, however, are useful in describing system dynamics. The soil data base structure and data aggregation procedure(s) for an assessment will depend on the importance of specific map unit components and spatial distribution of those components.

WHAT MAP UNIT CHARACTERISTICS ARE NEEDED?

Soil map units must be synchronized with other landscape attributes (e.g. landuse, vegetation, climate) so relationships that naturally occur in the landscape are portrayed on maps. In other words, the portrayal of relational landscape attributes must be synthesized to produce correlation of data layers in geographic information systems. Failure to properly correlate the attributes will result in discordant landscape segments where unrelated kinds of attributes intersect.

Ideally, map units must represent delineation of segments of the landscape for which natural processes cause an individual segment to be different from neighboring segments. The kinds and extent of soils in a region need to be determined from soil map units delineated on a map and described in terms of their composition. The proportion of map unit components must be quantified at a level of reliability required by the data quality needs of assessment models. If minor components of map units prove to be important to modeling landscape processes and assessing environmental concerns, they must be retained in regional-scale data bases.

WHAT ARE THE NEEDS FOR SOIL DATA?

In regionalization, processes that realistically apply to individual soil pedons or to groups of soils with selected characteristics in common need to be extrapolated to large regions. Differences in properties from one layer of the soil to another may have an important effect on process model predictions. If process models used in an assessment are sensitive to within soil variability, then data for individual pedon horizons or for major horizons representing a group of pedons in the same class are needed. These data must be retained in and readily accessed from a soil data base.

Spatial variability of soil properties within a region is usually much too complex to apply models to every contrasting soil horizon and sum results across the region. There is simply not enough computer power to simultaneously run the models at this level of spatial resolution for a large region. Conversely, if models use mean values for the region an erroneous result may be obtained because relationships are nonlinear.

What is needed is a system of relational data sets that facilitates retention of important characteristics while moving from one scale to the next. As pedologists, we must develop realistic approaches that deal with this across scale issue. We need to quantify the spatial variability of soil components within map units at a given scale and seek ways to aggregate soil data in such a manner that the integrity of important soil properties is preserved.

APPROACHES TO GLOBAL SOIL DATA BASES

For the most part, "currently available" or "in progress" regional or global scale soil data bases stand alone with respect to map unit legend, map unit composition and relationship to other scales of mapping. Bowman (1989) has recently reviewed global soil maps and data sets, and summarized their usefulness and limitations for use in global environmental assessments. The following soil data bases and their respective approaches are presented as examples of soil data at different mapping scales and are discussed in terms of their potential use for regional or global assessments. Linkages between these data bases or others like them need to be constructed to enable their use in the transfer of local-scale process results to global-scale systems. These soil data bases need to be fully evaluated for application and quantitative reliability in assessment of environmental concerns.

FAO (1:5 000 000)

The FAO Soil Map of the World (FAO/UNESCO, 1971-1981) is a classification of map units that can be used to reflect general soil patterns in a large region. This data base does not provide information on soil properties of individual pedons or classes of soils as needed for process models. Furthermore, soil spatial variability depicted by maps at this scale is not adequate for simulation of landscape processes.

SOTER (1:1 000 000)

Compilation of soil information has recently started in pilot areas using procedures developed for a global soil and terrain (SOTER) digital data base. The

SOTER uses a universal legend based on soil properties and is designed to accommodate all national classification systems. Separate attribute files are used to record characteristics of map delineations, terrain components and soil layers. Each map unit is described by one to three terrain components and represented by one to three soils. The proportion of each terrain component in a map unit is recorded in the terrain attribute file. Where there are existing soil maps, SOTER map units are generalizations of source map units (Shields and Coote, 1989). Although local-scale soil maps, where available, are used to construct the SOTER map, there is no apparent attempt to link data on map units or map unit components between scales. SOTER attribute files provide both data on soil properties and estimates of the proportion of kinds of soils in map units. Terrain components and soils of lesser extent fall through the cracks of the system and are lost from the data base. Completion of global coverage with the SOTER is expected to require about 20 years.

STATSGO (1:250 000)

Under the National Cooperative Soil Survey in the United States, the Soil Conservation Service is compiling a regional scale State Soil Geographic Data Base (STATSGO) from existing detailed soil maps (Reybold and TeSelle, 1989; Bliss and Reybold, 1989). As many as 21 components and their estimated proportions in the map unit are allowed. Map unit components, mostly phases of soil series, are linked through a map unit use file to appropriate soil interpretations records. In this manner, soil map units can be linked to soil properties needed to support process models. A link has not been established between the STATSGO map and the more detailed soil maps from which they were compiled. Map unit composition has been

based on "desk top" transects of maps and not "ground truth". With this approach, map unit composition is based on map unit names instead of components of map units from the larger scale map.

DDRP (1:24 000)

A project designed to predict the future effects of acidic deposition on soils and surface waters, the Direct Delayed Response Project (DDRP) used soil mapping and sampling of soil groups to characterize soil properties within regions (Lee et al., 1989a). A statistical selection of watersheds within a defined region and a probabilistic sampling frame provided a statistical basis for the extrapolation of measured and modeled results from the watersheds to the region without surveying the entire region. Map unit composition was quantified from randomly selected transects and the proportion of each component recorded to the nearest 5 percent. Map unit components (mostly phases of soil series) were grouped into classes based on soil properties considered to be important in the assessment of the effects of acidic deposition on surface water chemistry. These classes were characterized by sampling and laboratory analyses of six to eight pedons representing each class. This approach to a regional data base provided data on soil properties required for models as well as soil distribution in the landscape at the required scale. Map unit components were linked to important soil characteristics and taxonomic classification, and could be easily linked to appropriate soil interpretations records (Lee et al., 1989b). The extent of field work required in this approach may limit its usefulness for large regions or continents. This approach to regionalization, however, may be very useful in characterizing regions and in determining representativeness of study

sites used to develop and test models. The quantitative nature of the SDRP data base and the procedure used to group soils demonstrated a realistic approach that could be used in linking soil data bases.

CHARACTERISTICS FOR NESTING SOIL DATA BASES

Nesting was perceived as a method for linking spatially distributed terrestrial attributes of different scales. It is a system that will allow us to "zoom in" to local-scale maps for a closer look at the heterogeneity of individual regional-scale map units and "zoom out" to regional-scale with important data or results from soil processes. Characteristics needed for nesting soil data bases include a global skeleton or framework, delineation of naturally occurring segments of the landscape, and quantification of map units and map unit components that are correlated on soil properties.

Framework

A geographic framework is needed to facilitate understanding and characterization of global ecosystem patterns and their components. In addition to providing a mechanism for determining within-region variability and a means to measure representativeness of sites within regions, a framework is needed to maintain integrity of attribute composition when moving from a map of one scale to another. A geographic framework, such as the one constructed by Omernik (1987) for delineating ecoregions of the United States, depicted terrestrial ecosystems by conceptualizing distinct patterns of terrestrial characteristics. Omernik (1987)

hypothesized that ecosystems and their components display regional patterns that are reflected in spatially variable combinations of factors including soils, geology, climate, vegetation and physiography.

Map units delineated on natural landscape units

May units designed to represent naturally reoccurring segments of the landscape will allow linking of spatially distributed terrestrial attributes at different scales of mapping. Map units that are instead designed for a specific use or interpretation or delineated along artificial boundaries will cross natural landscape breaks and therefore, not permit nesting. For environmental assessment, map units must convey the relationship between soil distribution and the landscape at a scale that captures important soils.

Quantification of map unit components

Quantification can only progress from fine to coarse resolution. Therefore, map unit composition must be described for the largest scale (finest resolution) map of those being nested. Composition needs to be rigorously quantified for reliable data aggregation, linkage between scales, and regionalization. Map unit composition can be quantified at any map scale, but must be consistent for nested map units of different scales and will need to be updated as new data become available.

Soils correlated on properties, not interpretations

Soil properties should be used as the basis for separation of soil classes (e.g. soil series). Soil properties that influence productivity of vegetation, biogeochemistry and

hydrology are important in environmental assessment. If soils are correlated on important properties with respect to environmental concerns, they can later be grouped for a specific concern to reduce data base size and improve modeling efficiency.

CONCLUSIONS

The need for soils data to assess environmental concerns on regional and global scales demands the development of flexible, multipurpose and scale transferrable data bases. We can no longer think of soil surveys as being conducted for a specific purpose and soil map units as delineations of the landscape having a singular response to use and management. Map units must be aligned with recognizable repeating segments of the landscape, that are correlated on the basis of differences in the proportion of map unit components.

Components of map units must represent actual differences in soil properties, not differences in taxonomic class. These kinds of soil will need to be grouped into classes to facilitate the most precise predictions for a specific use or concern. The relative proportion of map unit components needs to be determined quantitatively and landscape characteristics of their occurrence described. Some thought must be given to defining separate map units on the basis of kinds and extent of contrasting inclusions.

Procedures need to be developed for "nesting" levels of mapping in a way that will allow transfer of spatial distribution, and physical and chemical properties of soils that are applicable to soil processes from one scale to another.

Through careful description and quantification of the soil map unit, spatial variability can be linked to characteristics of the map unit components. Field data and laboratory data of individual pedons or groups of similar pedons can be used to characterize the kinds of soil (e.g., soil series) in the landscape. These data can be input to process models to simulate effects of stressors on the environment.

By developing an ecoregion framework for the orderly nesting of soils data bases and by employing procedures for aggregation of data, modeling of systems and extrapolation of results individual processes can be scaled-up to regions or continents. The occurrence of small areas of contrasting soil may be of great importance in explaining the hydrology, habitat, buffering capacity or trace gas emission of the landscape. These key segments of the landscape must not be lost or distorted in the scaling-up process. The extent of soil bodies and their position in relation to other soil bodies and to surface waters in the landscape are important to understanding and assessing effects on terrestrial systems.

REFERENCES

Bliss, N.B. and W.U. Reybold. 1989. Small-scale digital soil maps for interpreting natural resources. J. Soil Water Conserv. 44(1):30-34.

Bowman, A.F. 1989. Distribution of the major soils of the world. p. 15-24. *In* A.F. Bowman. The role of soils and land use in the greenhouse effect. Background paper, International conference on: soils and the greenhouse effect. Wageningen, The Netherlands. 14-18 August 1989. ISRIC, Wageningen, The Netherlands.

Brown, R.B. 1988. Relevant interpretations of the 1990's. p. 65-81. *In* Proceedings of the International Interactive Workshop on Soil Resources: Their inventory, analysis and interpretation for use in the 1990's. Univ. Minn, St. Paul, MN.

Buol, S.W., F.D. Hole, and R.J. McCracken. 1980. Soil Genesis and Classification. 2nd ed. Iowa State Univ. Press. Ames, IA.

FAO/UNESCO. 1971-1981. Soil map of the world, 1:5 000 000. Vol I-X. FAO, Rome.

Lee, J.J., D.A. Lammers, M.J. Johnson, M.R. Church, D.L. Stevens, D.S. Coffey, R.S. Turner, L.J. Blume, L.H. Liegel, and G.R. Holdren. 1989a. Watershed surveys to support an assessment of the regional effects of acidic deposition on surface water chemistry. Eviron. Mgt. 13(1):95-108.

Lee, J.J., D.A. Lammers, D.L. Stevens, K.W. Thornton, and K.A. Wheeler. 1989b. Classifying soils for acidic deposition aquatic effects: a scheme for the northeast USA. Soil Sci. Soc. Am J. 53(4):1153-1162.

Nettleton, W.D. and B.R. Brasher. 1989. The taxajunct problem. Agron. Abstr. p. 269.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Ann. Assoc. Am. Geographers. 77(1):118-125.

Reybold, W.U. and G.W. TeSelle. 1989. Soil geographic data bases. J. Soil Water Conserv. 44(1):28-29.

Shields. J.A. and D.R. Coote. 1989. SOTER procedures manual for small scale map and data base compilation and procedures for interpretation of soil degradation status and risk (for discussion). ISRIC Working Paper and Preprint 88/2 (revised). ISRIC, Wageningen, The Netherlands.

Soil Survey Staff. 1975. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. USDA-SCS Agric. Handb. 436. U.S. Gov. Print. Office, Washington, DC.

Soil Survey Staff. 1983. National soils handbook. USDA-SCS Agric. Handb. 430. U.S. Gov. Print. Office, Washington, DC.

Wilding, L.P. 1988. Improving our understanding of the composition of the soil landscape. p. 13-35. *In* Proceedings of the International Interactive Workshop on Soil Resources: Their inventory, analysis and interpretation for use in the 1990's. Univ. Minn, St. Paul, MN.